DSN Research and Technology Support

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The activities at the Venus Station (DSS 13) and the Microwave Test Facility, both operated by the Development Support Group, during the 6-month period ending October 15, 1975, are discussed and progress is noted.

Successful remote operation of the Venus Station from Pasadena during a pulsar observing track is described, along with significant tracking of the planet Venus in an interferometric planetary radar mode. Completion of the first phase of the demonstration of long-distance (1.6-km) transmission of microwave power is reported, with an RF-to-dc conversion efficiency of better than 80% and 30 kW of dc recovered. Extensive support to the X-band radar and the Block IV receiver-exciter at the Mars Station (DSS 14) is reported, along with support to noise-adding radiometer (NAR) reliability experiments, antenna gain standardization, planetary radio astronomy, platform parameters very long baseline interferometry (VLBI), interstellar microwave spectroscopy, Venus/Ovro VLBI, and differential phase VLBI. Routine transmission of clock synchronization signals to the overseas complexes with 64-m antenna stations is also discussed, and extensive analysis of a reported problem with the DSS 14 HV dc power supply which resulted in excessive ripple voltage interfering with transmitter operation is described.

During the 6-month period ending October 15, 1975, the Development Support Group, in operating the Venus Station (DSS 13) and the Microwave Test Facility (MTF), supported various programs as discussed below.

I. Station Automation

In support of Network Monitor, Control and Operations Technology, a demonstration of a remotely operated, automated station is planned, using DSS 13 as the test station. Working toward this goal, hardware and software testing continued (Ref. 1). Communications between the Sigma-5 computer at JPL and the XDS-930 computer at DSS 13 proved to be a stumbling block (timing problems), and in an effort to resolve these problems, 570 h of intercomputer communications testing was performed. As the timing problems, data dropout, and other hindrances were resolved, testing of the rest of the system was also performed. In culmination of 83 h of system testing, an automated station under local (DSS 13) control was successfully demonstrated on March 20, 1975. The station was placed into a preconfiguration condition and antenna movement, system temperature measurement, and data collection from 7 pulsars were accomplished using only local input into the XDS-930 typewriter input.

Building on this base, full remote control of the station using a Sigma-5 computer at JPL was demonstrated in August 1975, with two separate observing periods of 6 h each, during which control was completely exercised from JPL without prior notification of changes in the antenna position being given to DSS 13 personnel. Testing to obtain reliability data is continuing.

II. Pulsar Observations

In support of the Radio Science experiment Pulsar Rotation Constancy, we provided 135 h of observations, during which data on the pulsars, tabulated in Table 1, were recorded. These data, from observations made at 2388 MHz, left-circular polarization, are used to determine precise pulse-to-pulse spacing, pulse shape, and pulse power content of the signals emitted by these pulsars.

III. Interferometric Planetary Radar

Continuing mapping of the planet Venus, 86 h of support were provided, during which 61 h of actual observing produced 207 data runs. (A run varies in length, being the round-trip light time to the target, the planet Venus.) In this experiment, the 64-m antenna at DSS 14 illuminates the target with a suitably coded signal, and after a round-trip light time has elapsed, both the 64-m antenna at DSS 14 and the 26-m antenna at DSS 13 receive the reflected signal. The signals are combined at DSS 14 and converted into power spectra by means of the discrete Fourier transform. The cycle is then repeated, with alternate transmit and receive periods. Approximately 1000 min of data have thus been received and transformed into power spectra during this reporting period. These observations are conducted at 2388 MHz using the 400-kW transmitter at DSS 14 as the illuminator.

IV. Noise-Adding Radiometer Reliability Testing

Using the DSS 13 26-m antenna, station receiver, and the noise-adding radiometer (NAR), total receive system temperature is automatically recorded during the night and weekend periods when the station is nonoperational. This continuous operation provides reliability data and, in addition, produces a radio brightness temperature sky map as Earth's rotation sweeps the fixed antenna beam across the sky. The antenna is positioned at a fixed azimuth and progressively different elevations to produce, in time, a complete sky map. During this period, 1075 h of data were gathered with the antenna positioned at an azimuth of 0 deg and at progressive elevations of 55 through 53.3 deg in 0.1-deg increments. Measurements are made at a frequency of 2295 MHz using right-circular polarization.

V. Antenna Gain Standardization

To check the gain of the network antennas, transfer gain standards are needed. To provide such standards, the 26-m antenna at DSS 13, whose gain is known, is used to determine the flux density of suitable radio calibration sources. During this period, measurements were made of radio sources Cassiopeia A, 3C123, and Virgo A (3C274), at a frequency of 2278.5 MHz, using right-circular polarization on the 26-m antenna. These data, taken semiautomatically using the NAR, were collected for a total of 20 h during this period.

VI. Microwave Power Transmission

The operational desk/console, consisting of an Interdata 7/16 minicomputer, teletype I/O, cathode ray tube display terminal, non-impact printer, and a control keyboard with a cassette tape system, was installed in the Operations and Data Processing building at DSS 13. The rectenna subarrays were installed on the collimation tower, and testing was performed. After measurement of energy distribution within the antenna beam, rectenna efficiency, reflected power, etc., a successful demonstration was performed during which 30.1 kW of dc power were recovered by the rectenna array, with an average RF-to-dc efficiency of better than 80%. (RF-to-dc efficiency, in this case, is defined as the ratio between the RF energy incident upon the rectenna array and the dc output from the array.) The system was subsequently demonstrated to the Satellite Power Team and various members of NASA, universities, and private industry. Inclement weather is awaited for further testing of the system.

VII. X-Band Radar

The production version of the buffer amplifier was installed and suffered a failure of one of the Logimetrics power supplies. The system was then removed for further testing and evaluation. Meanwhile, the transmit-receive waveguide switch was replaced, and the receive system temperature was improved 2.5 K. During subsequent testing, one of the klystrons failed. A spare klystron was installed, and the buffer amplifier was reinstalled and again suffered problems. Difficulties were encountered with body current monitoring, arc detector functioning, and interconnections within the buffer amplifier. The problems were solved, the system was made operational and, during subsequent full system testing, both klystrons failed, with cracked output waveguide windows.

Analysis of the failure indicated possible malfunctioning of one of the TWTAs in the buffer amplifier, and a crowbar circuit was added to the system to prevent drive to the final klystron in the event of oscillation in the buffer amplifier. The system was again made operational with one klystron installed, and a planetary radar track was successfully run with one klystron, 130 kW output power. Subsequent scheduled tracks were canceled because of problems with the computer data collection system.

VIII. Block IV Receiver-Exciter, DSS 14

Continued support was provided for a total of 222 manhours to the subsystem testing of the Block IV receiver-exciter at DSS 14. Problems with the X-band doppler chain were solved by cable and module replacement. The exciter configuration control and status assembly was installed, and additional problems were encountered with the doppler extractor modules and noise on the cabling. Cable replacement and careful work on the ground returns, along with relay and module replacements, aided in making the system operational and effecting transfer to operations.

IX. 100-kW Transmitter Installation in Australia and Spain

The support for the 100-kW transmitter installation was completed by shipment of the spare X-3060 klystrons to their stations. Special matched sets of shims, adapters, magnets, and socket tanks were also shipped. (The shim and adapters were necessary to compensate for varying lengths of the klystrons, along with irregularities in the mounting plates.)

X. Fourth-Harmonic Testing, DSN Klystrons

In anticipation of X-band operation with the Viking spacecraft, the level of the fourth harmonic of the S-band transmitter klystrons was measured. A specially designed and built (by Varian Associates) filter/analyzer was used to measure the harmonic output of the X-3060 klystrons operating at 100-kW output power. Measurements were also made on the X-3075 klystrons at 400-kW output power. Measurements, made before and after the standard harmonic filter, indicated that it was desirable to add additional filtering to assure that the fourth harmonic of the S-band transmitter output did not interfere with operation at X-band with the Viking spacecraft.

XI. Excess Property Disposal and Storage Area Screening

The recent series of personnel reductions and resulting reduction in the operating hours of the Venus Station, coupled with a change in the emphasis of the station's mission, indicated the desirability of reducing the property inventory. All portable test equipment within the Development Support Group has been reviewed, and all items which have no foreseeable usage in its revised mission have been placed with the Property Department for disposal through the usual channels. Additionally, temporary personnel have been hired to aid in screening the storage areas to separate and arrange all material held therein. A significant amount of surplus and scrap material has been produced as a result of these activities.

XII. Mars Station HV (90-kV) dc Power Supply

Reported excessive ripple voltage on the output of the 2-MW, 90-kV dc high-voltage transmitter power supply at DSS 14 prompted an intensive investigation. After ascertaining that none of the phases was missing on the input 400-Hz three-phase line, and observing that the input 400-Hz voltages and currents were balanced on the three phases, a decision was made to open up the power supply and check the rectifier diodes.

Upon opening the rectifier section of the power supply, it was observed that the insulating oil was clear with no undue coloring. The rectifier diodes are arranged in series, with voltage and current balancing resistors and capacitors, into a stack. The stacks, which contain 78 diodes each, are again arranged in series to provide the necessary peak inverse voltage rating. Twelve of these stacks are thus arranged into an assembly, with one assembly per phase. Figure 1 shows how the assemblies are fitted between wooden rails and electrical contact is made with copper tubing. On the right in the photograph can be seen a diode assembly, with one stack visible at the top. The assembly in the center is an array of peak clipping selenium rectifiers designed to prevent excessive peak alternating current voltages from being applied across the diode stacks whenever transient disturbances occur on the alternating current line.

It was decided to test the stacks in a manner similar to that originally used by the manufacturer. Two tests were used, a forward voltage drop test and an inverse voltage current test. In the forward voltage test, direct current voltage was applied in the forward direction across the stack and adjusted so that the forward current was 10 A. The voltage drop across the stack was then measured. In the inverse current test, 20,000 V direct current was applied across the stack in the inverse direction, and the resulting current was measured. Exploratory measurement on a spare stack indicated that repeatable measurements could be made in the reverse direction by using a General Radio high-voltage ohmmeter set for 500 V output voltage. Measurements taken with this instrument and with the 20-kV test voltage indicated the same resistance within 4%, so measurements were continued using the high-voltage ohmmeter. A Hewlett-Packard Model 6483C current-regulated power supply was used for the forward voltage drop measurements and, to ensure minimization of heating effects, the voltage drop was measured with a Hewlett-Packard Model 3430 digital voltmeter 5 s after the 10-A forward current was established by turning on the power supply. Figure 2 shows the interconnection of the equipment. Examination of the test data indicated that no diodes were open but one stack most likely had one diode shorted. Each stack has a nominal reverse voltage rating of 49,200 V, while maximum peak inverse voltage across each stack at 90 kV dc output voltage is only 7875 V; one failed diode therefore introduces minimal additional stress.

Inasmuch as the rectifier stacks were good, transformer secondary voltage balance was checked. Temporary reconnection of the HV supply was made with the top off for access. Using a test lead made of a high-voltage stick with a large fuse clip connected to an electrostatic voltmeter, secondary transformer voltages were measured at a dc output voltage of 40 kV and an output current of 7.4 A. The secondary phase to neutral voltages were all balanced within 0.6%, so transformer problems were ruled out. With no apparent fault in the transformer/rectifier, the wave shape of the input 400-Hz line on the primary of the transformer was then examined. Since this transformer is connected in a balanced delta on the primary, waveform measurements were made using two Tektronix HV probes connected to a differential input oscilloscope. Figure 3 shows that the waveform is distorted, with what appears to be a strong sixth harmonic component. Waveform measurement of the ripple voltage appearing at the input to the filter choke also reveals a strong 2400-Hz component which is strongly sinusoidal, as indicated by Fig. 4. Measurements of the inductance of the filter choke revealed that it had decreased from a nominal nameplate value of 1.0 H to a measured 16 mH, while the spare choke measured 1.35 H. The spare choke was placed into service, and measurements of the ripple voltage indicated that, at 20 kV dc output voltage, the ripple on the choke input was 16 kV peak-to-peak, while the ripple on the output of the filter choke was 46 V peak-to-peak. It is believed that, in the absence of any faults found with the transformer/rectifier, the high value of ripple on the filter choke input is caused by the strong 2400-Hz component on the 400-Hz input to the primary of the transformer/rectifier. The most likely cause of this 2400-Hz component is a high impedance in the frequency converter at this frequency, as evidenced by a no-load waveform check, which revealed that the frequency converter output waveshape is a near-perfect sinusoid when not furnishing power to the transformer/rectifier.

Experimentation with an unbalanced pi ripple filter indicates that the ripple voltage on the choke input can be reduced substantially by connection of a relatively small value capacitor to bypass the ripple back to the power supply. Figure 5 illustrates that, at 20 kV dc output voltage, the peak-to-peak ripple voltage is reduced from 16 to 1 kV by connection of a capacitor having a nominal value of 0.15 μF to bypass the ripple back to the power supply return line.

Further testing is under way to determine the optimum size capacitor that will reduce the ripple to an acceptable level while limiting capacitor charging current to a safe level which will not harm the rectifier diodes.

XIII. Planetary Radio Astronomy

In support of the Planetary Radio Astronomy experiment, observations are made of the planet Jupiter and various radio calibration sources. Total receiving system temperature, both on- and off-source, is measured. Received flux density of the source can then be calculated. The measurements are made at 2295 MHz, both left-circular polarization and right-circular polarization, and utilize the 26-m antenna, the station receiving system, and the NAR. Observations, in addition to those of Jupiter, were made of the sources shown in Table 2, while the data were collected semi-automatically under the control of the NAR. A total of 177 h of data were thus collected.

XIV. Platform Parameters VLBI

The objective of this activity is the refinement of the application of the VLBI technique to measurements of navigation platform parameters, specifically UT1, polar motion, and relative station locations. The support given by the Venus Station (DSS 13), a total of 11 h of observing, is to aid in the development of a position catalog of 50–100 compact extragalactic radio sources for use as navigation sources. During the 11 h, 65 sources were observed, with DSS 63 (Madrid) as the other VLBI station operating at 2290 MHz.

XV. Interstellar Microwave Spectroscopy

The objective of this activity is the measurement of the location and abundance of complex interstellar molecules, involving recombination line study in various regions. DSS 13 provided 15-1/2 h of observing, during which time the regions Orion A and MON-R2 were studied at 2272.62 MHz. These measurements utilize the 26-m antenna, the station receiving system, and the NAR.

XVI. Venus/Ovro VLBI

The objective of this experiment is to make high-resolution observations of the strongest 100 radio sources in the complete 3C catalog. DSS 13 provided 123 h of observing, during which 159 source observations were made in the VLBI mode, with the Owens Valley Radio Observatory as the other station. Observations were made at 2310 MHz and utilized the 26-m antenna, a special mixer, and a special video tape recorder for data recording.

XVII. Differential Phase VLBI

The objective of this experiment is to investigate and demonstrate a technique of obtaining accurate phase measurements by VLBI observations. In conjunction with the Owens Valley Radio Observatory, 32 h of observations were made at 2290 MHz using the DSS 13 26-m antenna, the station receiver, and a special video recorder for recording data.

XVIII. Clock Synchronization Transmissions

Routine transmissions, typically 1 h in duration each, have been made as scheduled. Additionally, required testing to assure operability has been performed. With the completion of the overseas 64-m antenna stations, timing signals are distributed to the 26-m stations by the 64-m stations. Therefore, transmissions are made only to the 64-m antenna stations in Spain and Australia. Fifteen transmissions were made to DSS 42/43 in Australia, while 14 transmissions were made to DSS 61/63 in Spain.

Reference

1. Jackson, E. B., and Price, A. L., "DSN Research and Technology Support," in *The Deep Space Network Progress Report 42-27*, pp. 107–111, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1975.

Table 1. Pulsars observed at DSS 13 (April 16 through October 15, 1975)

0031 − 07	0628 − 28	1133 + 16	1911 − 04	2045 − 16
0329 + 54	0736 − 40	1237 + 25	1929 + 10	2111 + 46
0355 + 54	0823 + 26	1604 − 00	1933 + 16	2218 + 47
0525 + 21	0833 − 45	1642 − 03	2021 + 51	

Table 2. Radio calibration sources observed at DSS 13 (April 16 through October 15, 1975)

3C17	3C123	3C218	NGC 7252	Virgo A
3C48	3C138	3C348	PKS 0237-23	
3C58	3C147	3C353	PKS 2134	

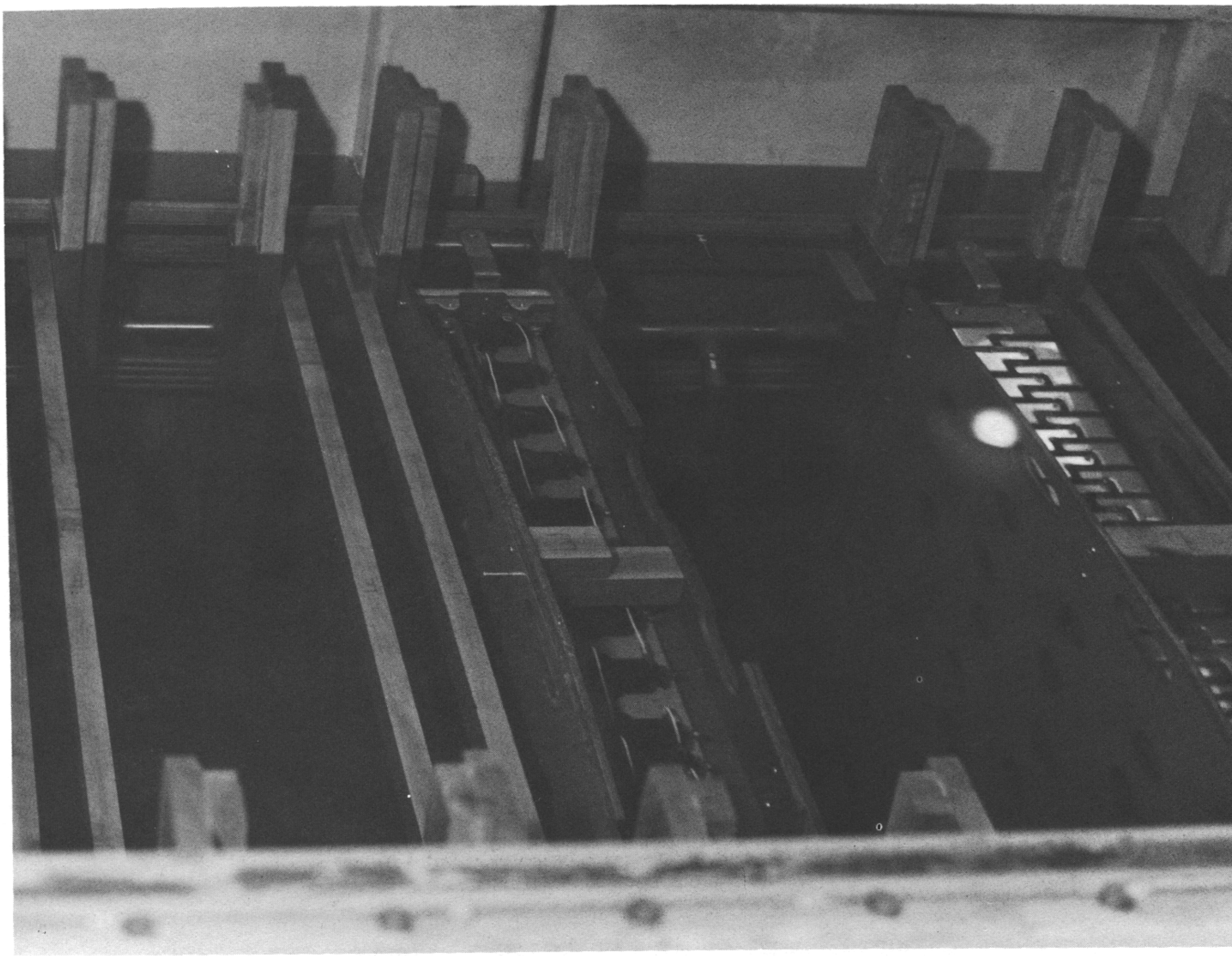

Fig. 1. Interior construction of rectifier side of HV dc power supply

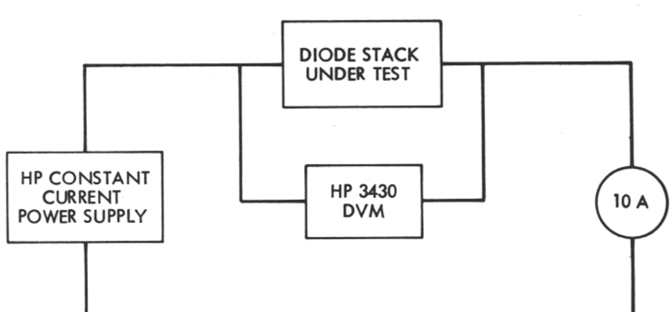

Fig. 2. Forward voltage drop test configuration

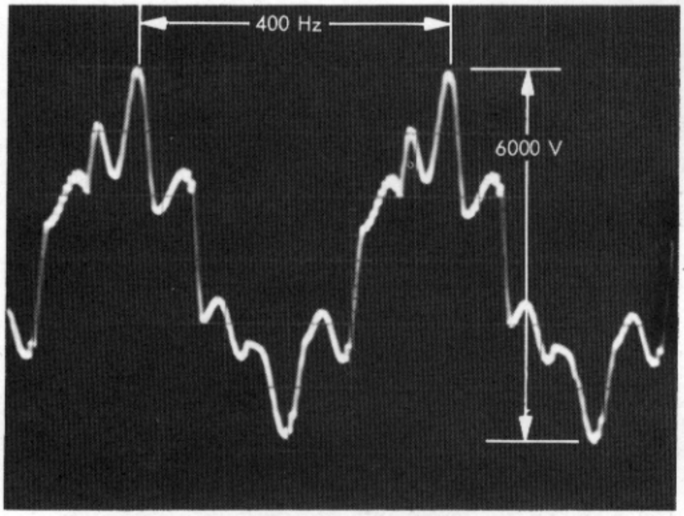

Fig. 3. Voltage at 400 Hz input to transformer, DSS 14 HV dc power supply

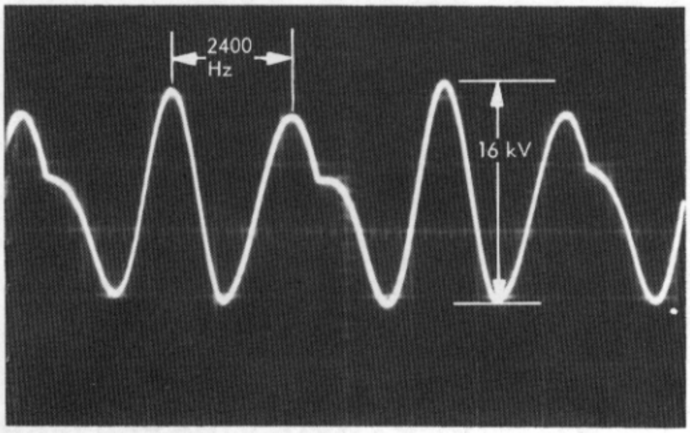

Fig. 4. Voltage at filter choke input, DSS 14 HV dc power supply

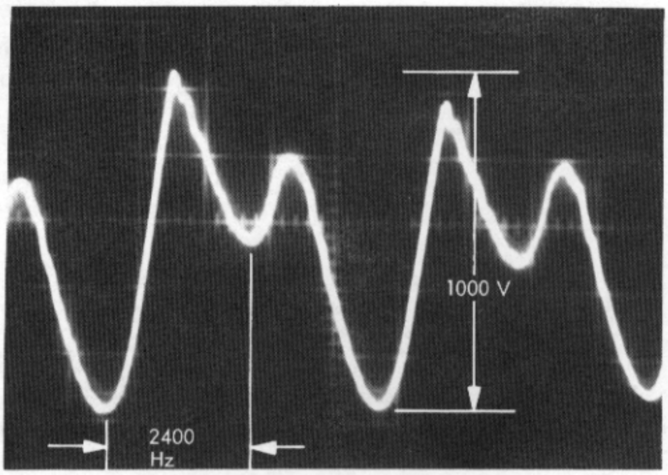

Fig. 5. Voltage at filter choke input, DSS 14 HV dc power supply, with added 0.15-μF filter capacitor